EMS in HCI: Challenges and Opportunities in Actuating Human Bodies

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Abstract

Electrical Muscle Stimulation (EMS) recently received considerable attention in the HCI community. By applying small signals to the user's body, different types of movement can be generated. These movements allow designers to create more meaningful and embodied haptic feedback compared to vibrotactile feedback. This advantage also comes with further technical and practical challenges which need to be tackled. These challenges include a fine grained calibration procedure and a close contact to the user's body at specific on-body locations. This tutorial gives an overview about current research projects, challenges, and opportunities to use EMS for providing rich embodied feedback followed by a hands on experience. The main goal of this tutorial is that participants get a basic understanding of how EMS works and how systems that are using EMS can be developed and evaluated.

Author Keywords

Electrical Muscle Stimulation; Haptic Feedback; Tutorial.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Input devices and strategies; Haptic I/O.

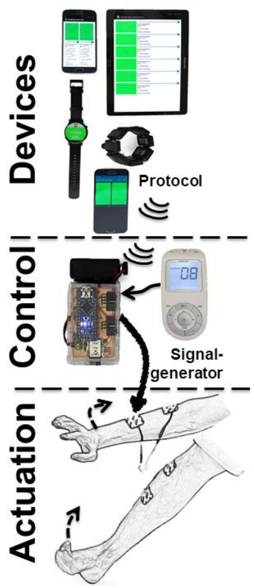

Figure 1: Let Your Body Move Toolkit: Communicates with different devices via BluetoothLE. It uses EMS generators such as the Sanitas SEM43.

Introduction and Background

Haptic feedback for mobile usage has mainly been limited to vibro-tactile feedback as known from mobile phones and wearable wristbands. In the recent years, however, electrical muscle stimulation (EMS) has received considerable attention as a mean to provide rich haptic feedback. While EMS has already been used in medicine, physiotherapy, and sports for muscle recovery [9], the application as feedback methods provides one core advantage compared to other haptic feedback methods. EMS is capable of actuating the user's body so that certain muscles contract. This contraction can result in a specific movement of the user (e.g., movement of the arm). Thus, it is not only possible to convey information but also to induce movement. Due to this advantage, EMS has been used for realizing different application scenarios. Examples include twisting the leg to change the walking direction of pedestrian for navigation [7], to communicate emotions [2], to present notifications [10], or to communicate the desired way of usage of objects [3] (e.g., shake a spray can prior to use). The main drawback of EMS as feedback technology is that the application is more complex compared to vibro-tactile feedback. The placement of the electrodes as well as the signal highly influence whether the feedback is perceived as slight tickling or muscles are actually actuated.

In this tutorial we will provide an introduction on how to use EMS as a feedback method. We particularly focus on how to place electrodes, calibrate an EMS system, and conduct user studies. We will address challenges and provide an overview of lessons learned we gained throughout different projects realized with EMS as a feedback method.

Challenges

Challenges to use EMS are mainly caused by the individuality of users [11]. This results in differences in the position of motor neurons, different skin resistances, thickness of tissue layers, muscle strength, and sensitiveness of users. Also EMS is an on skin technology [1], therefore EMS needs skin contact through electrodes. This results in an individual placement of the electrodes and an individual calibration. As EMS is interfacing the body of the user, considerations in terms of user acceptance, ethics, and safety need to be discussed.

Intended audience

The tutorial addresses HCI researcher and people who are interested in EMS. There is no previous knowledge about EMS necessary.We will provide a general instruction of the technology and safety instructions. We will also provide hardware so that participants can explore EMS feedback during the course.

Learning goals

After the course participants gained a basic understanding of EMS as a feedback method, we will introduce the “let your body move” toolkit [5] (cf., Figure 1). Further we will provide knowledge on how to design and conduct simple EMS studies and raise awareness on ethical and safety aspects.

Covered Topics

EMS Basics

There are different signal generators (e.g., Figure 3) used for EMS which each are capable of generating different signal shapes. We will present the most common signal shapes and their parameterization. This includes typical current values, frequencies, and pulse width. We will discuss comfort and safety aspects with regards to the parameters. We will introduce the Let Your Body Move Toolkit [5] for manipulating EMS strength via mobile phone.

Figure 2: Carbon rubber electrodes (left), self adhesive electrodes (right). Both are available in different shapes and sizes. Carbon rubber electrodes can also be cut in smaller sizes (top left) and molded in silicon (bottom left).

Figure 3: Different EMS devices are available.

Types/Size of electrodes
We will consider different types of electrodes such as self adhesive electrodes, carbon rubber electrodes, and metal electrodes (cf., Figure 2). The electrodes need to be attached in different ways to use, some electrodes need conductive gel or tapes to increase the conductivity between electrode and skin.

Placement of electrodes
The next part of the tutorial deals with understanding the correct placement of the electrodes on the skin. We will present the placement of electrodes on various muscle (e.g., Figure 4) and participants will explore the placement themselves.

Study procedure for EMS based user studies
A study with EMS needs specific treatment of the participants such as clear introduction on the technology and consent forms, which should also address risks and safety information. The participants have to confirm that they have no relevant health issues and agree to get electrodes attached to their bodies by the instructor. After that there should be a step by step introduction to EMS to allow the participant to get used to the sensation. For reproducibility of the user study, EMS parameters should be reported such as frequency, pulse width, voltage, and current.

EMS Prototyping Toolkit
The Let Your Body Move Toolkit [5] shown in Figure 1 is a rapid prototyping Toolkit for EMS. It was evaluated in different courses and demos [4, 6, 8]. This Arduino Nano based Toolkit enables a galvanic isolated intensity regulation for maximum safety. It can communicate via Serial (USB) or BluetoothLE over an human readable communication protocol. The Toolkit does not create any EMS stimulus – it can only decrease the current an external EMS device generates. There are some example applications using the toolkit with an Android device. These applications can control more than one hardware set and communicate with other devices such as the Myo device from Thalmic Labs. More information on the toolkit can be found on the toolkit‘s page[1].

Learning Objectives
The attendees will be able to use EMS as a feedback method. They will have an overview about existing work on EMS in HCI. They will be able to choose the parameters to actuate muscle movement. They will also be aware about risks (ventricular fibrillation, bleeding, pain, skin irritations, muscle cramp, discomfort, etc.) and challenges of EMS. They are able to follow the safety instructions and avoid these risks. They will learn how to introduce EMS to participants of a user study, they know basic techniques for placing electrodes. They can run user studies with EMS and know which parameters to report. The attendees will also be familiar with the Let Your Body Move Toolkit.

Biography
Tim Duente is a researcher of the Human-Computer Interaction Group at the University of Hannover. He is interested in on-skin technologies, with an focus on how to turn the users body into an input/output device for a more natural human computer interaction.

Max Pfeiffer is an associate researcher of the Situated Computing and Interaction Lab at the University of Muenster. His research is in human-computer interaction, including situated, ubiquitous, and wearable computing with a focus on haptic feedback and spatial interaction.

[1] https://bitbucket.org/MaxPfeiffer/letyourbodymove/wiki/Home

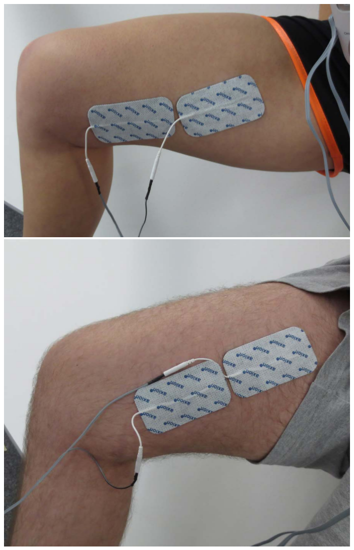

Figure 4: Right legs of participants during a user study. The electrode placement differs slightly between both images.

Stefan Schneegass is a professor of human-computer interaction at the University of Duisburg-Essen, Germany. His research focuses on novel interaction techniques for mobile, wearable, and ubiquitous devices. He received his Ph.D. from the University of Stuttgart.

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